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Reducing microplastic fiber shedding from hand-washed polyester.

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Introduction

The presence of microplastic fibers (MPFs) in oceans, soil and humans is a major ecological and health concern. A significant amount of MPFs are generated through the washing of textiles. Two-thirds of the world does not have access to laundry machines; the majority of garment washing is done by hand. However, most MPF research has focused on machine-laundered fabric. Moreover, while mitigation strategies such as coatings have been introduced to prevent MPF release, every prior study on MPF-reducing coatings utilized machine laundering. The aim of this work was to understand if such coatings are also effective at reducing MPF release when fabrics are washed by hand.

Methods and Materials

This investigation focused on MPF release during hand washing, utilizing two different constructions (dyed black and green) of 100% polyester fabrics (coated and uncoated) hand-washed in deionized (DI) water, tap water, and water sourced from Lake Ontario.

Results and Discussion

Our data indicates that water containing more total dissolved solids (TDS) results in a greater number of MPFs released per wash regardless of the fabric coating. Uncoated fabrics hand washed in water sourced from Lake Ontario released ~ 200% and 240% more MPFs/g compared to samples washed in DI water, for the green and black polyester, respectively. Additionally, the increase observed in the number MPFs released for the coated samples were ~ 540% and 210%, respectively. However, hand-washing in higher-TDS water significantly decreased the length distribution of released MPFs. The mean length of MPFs released from the uncoated black polyester hand-washed in DI water was ~ 1.2 mm, whereas it was only ~ 0.5 mm for polyester hand-washed in water sourced from Lake Ontario, with zero MPFs longer than 2 mm observed. This indicates that hand washing in higher-TDS water can further fracture MPFs even after their initial release. A coating shown to lower MPF release during machine laundering was also explored, to understand its efficacy at reducing MPF release during hand washing. The efficacy of the coating varied substantially between fabric constructions. MPF release was reduced 92%, 88%, and 77% when the green polyester was hand washed in DI, tap, and lake water, respectively, whereas these reductions were only 30%, 26%, and 37%, respectively, for the black polyester.

Conclusion

This work confirms the efficacy of anti-MPF coatings when the fabric is subjected to hand-washing, and highlights the critical role of water TDS on the amount of MPFs ultimately released into the wash water. Future work will investigate the mass of MPFs released to better comprehend how water TDS affects washing synthetic fabrics, both in terms of total plastic emissions and the size distribution of the released microplastic fibres.

Proof-of-Concept of an End-of-Life Sensor for Liquid-Repellency Monitoring of Medical Gown Fabrics.

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Introduction
Barrier protection is a vital aspect of personal protective equipment (PPE) within healthcare. For instance, the protection provided by medical gowns aid in healthcare-associated infections (HAI) control and prevent cross-contamination between medical personnel and patients. This type of medical attire typically employs a durable water repellent (DWR) finish to enhance its protective function. However, the performance of this barrier may gradually deteriorate over its service life without visible signs, hence posing a risk to health and safety. This research focuses on developing a DWR end-of-life (EoL) sensor that can detect a loss of water repellent properties in medical gown fabrics during service.

Materials & Methods
The validation of the sensor was conducted by comparing the results of the sensor measurement with a water contact angle measurement. It was performed on a cotton/polyester medical gown fabric with a fluoropolymer-based DWR finish (Textiles Monterey, Drummondville, QC) exposed to immersion in bleach for durations of zero to nine days. Sensor validation was also carried out with level 4 reusable surgical gowns (R-MOR-Tex™) donated by K-Bro Linen Systems (Edmonton, AB, Canada). The gowns were in varying life cycle stages; some were brand new, while others had undergone between 5 and 95 cycles of laundering prior to their removal from service for various factors. Specimens were cut from the critical zones of the surgical gowns.

Results & Discussion
The sensor developed includes a magnetic rectangular frame with a window and two metal electrodes located on each side; when performing the test, it is attached onto the fabric using a magnet. Sensor measurements are performed by dispensing a precise saline solution into the window of the sensor; a multimeter is then used to measure the resistance after two minutes. A finite resistance indicates a water-repellent fabric, while an overload (OL) reading signifies that the DWR finish has deteriorated.

In the case of the bleached specimens, the results from both the contact angle and sensor measurements indicate that the water repellent properties were lost after day 6 of immersion in the bleach solution. Similarly, for the used surgical gowns, a good correlation was obtained between the results of the contact angle and sensor measurements.

Conclusion
This study demonstrates the potential application of an EoL sensor to predict the water repellency behavior of the DWR finished fabrics. The correlation obtained between the sensor and contact angle measurement results validates the accuracy and reliability of the EoL sensor developed, along with the methodology for its use. Its ease of use will enable greater user accessibility, and its simple construction will facilitate a seamless deployment within the healthcare sector, thereby supporting health measures to mitigate the spread of HAIs.

Setup Development and Comparative Analysis of the Infrared Performance of Fabrics.

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Introduction

Typical approaches to high solar exposure involve reducing clothing insulation to maximize heat dissipation. However, extended exposure to sunlight can adversely affect physical performance during strenuous activity. It leads to an increase in skin temperature and a perturbation in the thermophysiological balance of the body. Thus, proper clothing is vital for radiation protection. While most studies emphasize the interaction between solar radiation and fabric color, a deeper understanding of the effect of the different fabric properties are essential for better wearer protection. Additionally, existing methods to evaluate infra-red (IR) performance of fabrics are limited in terms of regulation of solar intensity and impact of heat accumulation for instance. Consequently, the current research aims to develop a novel IR solar testing setup to evaluate the effect of fabric parameters on their solar and thermal outcomes.

Materials and Methods

The IR box includes an AM1.5G simulated solar source covering ultraviolet, visible, and infrared light, a sample holder, and light sensors and thermistors situated on both sides of the specimen. The IR box was calibrated using enhanced aluminum mirrors of known solar properties. Tests were conducted with 24 fabric samples (woven and knitted) of varying fibre contents, manufacturing techniques, coatings, colors and physical parameters collected from lululemon's internal library and test fabrics. IR performance in terms of light-material interaction parameters (transmittance, reflectance and absorbance), temperature variation, and IR images was evaluated over a period of 20 min. The results were based on the mean values obtained from three independent trials for each sample.

Results & discussion

The fabrics tested covered a wide spectrum in terms of transmittance (3.6% to 37%), reflectance (17% to 58%), and absorbance (25% to 76%). In general, the fabrics showed more tendency to reflect light than transmit or absorb it. A subset of 21 fabrics with a similar whitish color were used to analyze the effect of the fabric thickness and aerial density on the three light-material interaction parameters. Transmittance decreased linearly with the fabric thickness (R^2 = 0.78), in agreement with the Beer-Lambert law. It also showed a strong correlation with the fabric areal density (R^2 = 0.85). On the other hand, the fabric reflectance and absorbance showed weak correlations with both fabric characteristics.

To study how color affects IR absorption, three fabrics with similar physical characteristics but different colors (black, white, and electric lemon) were tested. The black fabric absorbed light the most, followed by electric lemon, and white. The opposite trend was observed for reflectance and transmittance. This result is consistent with previous research regarding the color influence on solar interaction with matter.

Conclusion

A novel, standardized measurement protocol system for assessing fabric solar performance has been successfully designed and implemented. It showed that fabrics' light transmittance is controlled by their thickness and areal density. Similar trends in terms of the effect of fabric color as reported in the literature were observed. The IR box allows evaluating fabrics IR performance under controlled, simulated sunlight conditions. It will support the industry for the design of improved fabrics for high solar conditions.

Use of Parametric Design to Support Garment Customization for Individuals with Atypical Body Size/Shape.

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Introduction

During the 19th century, ready-to-wear clothing replaced custom tailoring due to lower production costs. This shift toward mass production ultimately gave rise to fast fashion, a model defined by rapid production, frequent style changes, and low-cost design. It has many drawbacks. Among them, fast fashion marginalizes people with physical disorders, such as scoliosis or kyphosis, as most clothing brands adopt standardized sizing systems, which assume bodily symmetry and 'ideal' proportions. A promising solution is mass customization of clothing using 3D modeling. With parametric design methods, clothing can be designed for individuals with continuous user input, leading to better-fitting clothes for bodies with atypical size or shape.

Methods and materials

The parametric design method has been demonstrated as a potential path to realizing customized design due to its flexibility, responsiveness, and efficiency. Specifically, using the CAD modeling software Rhinoceros, combined with its built-in visual programming platform Grasshopper, can generate custom-fitted garment models by establishing an algorithm-driven modeling process. This is the focus of this present research, which has been exploring the application of parametric design for customized garments for people with scoliosis and kyphosis. This presentation outlines the work to date, which has arrived at a procedure to adjust a base shirt pattern to a 3D model of a human torso (a male mannequin shown in figures 1 and 2), and a separate simulation that allows clothing to be tested with simulated forces (results of simulation shown in figure 2).

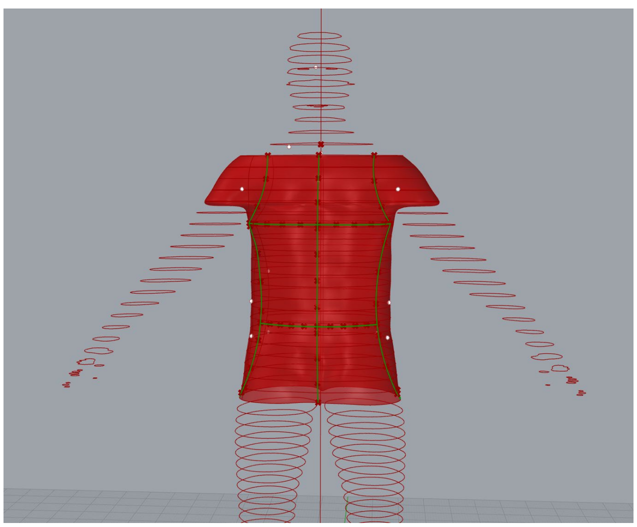

Figure 1: An image depicting how the mapping of the drawn pattern looks

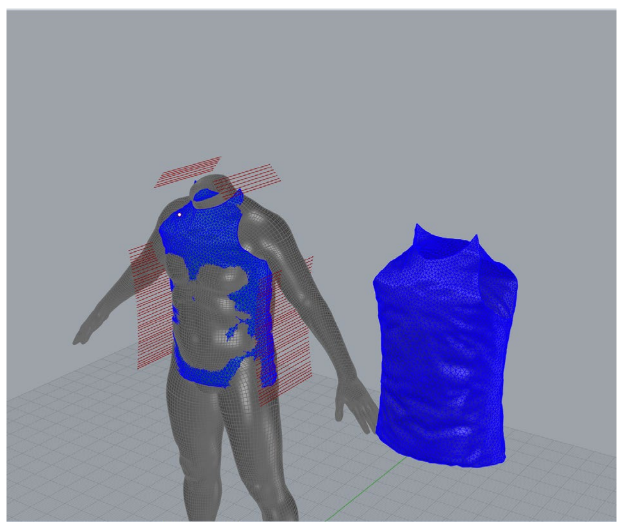

Figure 2: An image depicting the results of a previous simulation of patterning the clothes onto the model.

Results and discussion

This procedure is the outcome of extensive experimentation with parametric design processes, including a method that pulls patterns to the body (Figure 2) and a newer method that projects patterns directly onto the body (Figure 1). The pulling method involved dragging a projected pattern onto the body to approximate garment drape, enabling subsequent simulations with Rhino's physics engine Kangaroo. However, the accuracy of garment-body interaction was limited. The projection method, shown in Figure 1, shows greater promise, allowing patterns to be placed and edited across multiple body regions, with accurate body collision ensured through precise body mapping. However, the Kangaroo aspects of the pulling method have not yet been implemented. Once the physics simulation is integrated into the updated workflow, more precise tests will be run using Rhino, Grasshopper, and Kangaroo. This offers a strong foundation for work still to come in the project, which will involve applying the procedure to 3D models of different body shapes, including those with scoliosis or kyphosis, and employing gravity and material simulations.

Conclusion

The textile and manufacturing industry is dominated by fast fashion, limiting access to clothing that meets individuals' functional and medical needs. Applying parametric design/parametric modeling offers an innovative approach to mass customization for the garment design industry, enabling precise, user-specific sizing while reducing production costs. The procedures developed through this project and demonstrated in this presentation have potential for broad application, enabling sizing customization for clothes and a new wave of clothing for both medical and commercial use, tailored to each end user.

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Optical Sensor Integrated Textile Platform for Wearable Cardiovascular Function Monitoring.

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Introduction

Demand for wearable cardiovascular function monitoring has increased across healthcare, sports performance, and wellbeing applications. Photoplethysmography (PPG) is the most widely adopted optical sensing technique in commercial wearable devices. However, existing systems typically rely on rigid components, which limit conformity to the body and restrict long term continuous wearability. Textile based wearables provide a unique approach by enabling sensors to be seamlessly integrated into materials that are inherently flexible, comfortable, and worn closer to the skin.

Electronic yarns (E-yarns) fabricated using a patented manufacturing technology enable the integration of electronic components into textile yarn like structures without compromising intrinsic textile properties. This capability supports the development of textile integrated optical sensing platforms for cardiac monitoring. Nevertheless, challenges remain in understanding and optimising light textile interactions across different wavelength ranges, textile and polymer materials, and fabrication parameters.

In this work, a knitted glove integrated with optical sensing E-yarns is developed to form a transmittance mode PPG sensing system for monitoring pulse rate (PR) and blood oxygen saturation (SpO_2). The platform performance is evaluated through validation with human trials.

Materials and Methods

This work focuses on the development of a textile-based PPG sensing system that incorporates optical sensing E-yarns embedded with photodiodes (PDs) as receivers and light emitting diodes (LEDs) as emitters. The optical sensing E-yarns are fabricated through a controlled manufacturing process involving electronic component soldering, polymer encapsulation of solder joints and components, followed by textile braiding.

Controlled combinations of encapsulation polymer materials and polymer encapsulation geometry are first investigated, as the encapsulation layer forms the primary optical interface surrounding the sensing components. The optical behaviour of the encapsulated sensing elements is quantified to establish baseline transmittance and reflectance characteristics across visible and near infrared wavelength ranges.

Subsequently, optical characterisation is conducted to quantify light textile interactions by varying textile braiding materials and braiding parameters, with the braiding parameters directly influencing braid structure, while using the optimised encapsulation materials and geometries. This stepwise approach enables evaluation of how materials and parameters introduced at each fabrication stage influence overall sensor performance and how optical behaviour, particularly in terms of luminance, evolves with successive manufacturing steps.

Physiological signal extraction is performed using a knitted glove integrated with the optical sensing E-yarns. Two transmittance mode sensing configurations are implemented, including a single wavelength system using a red LED for PR estimation and a dual wavelength system using red and infrared LEDs for SpO_2 estimation. PR monitoring is validated with ten healthy participants, and SpO_2 monitoring is validated with five healthy participants. In both systems, the LEDs are powered and controlled using an Arduino Mega, while PD outputs are recorded using a data acquisition and logging multimeter system. Extracted PPG signals are post processed using Python to estimate PR and SpO_2 values.

Results and Discussion

Optical characterisation results demonstrate that materials and parameters introduced at each fabrication stage significantly influence the optical behaviour of the sensing E-yarns and the integrated textile system. At the encapsulation stage, variations in polymer material significantly affect baseline transmittance and reflectance by altering optical coupling around the sensing components. These results establish encapsulation material selection as a critical factor governing light throughput prior to textile integration.

Following optimisation of the encapsulation parameters, textile material selection and braiding parameters significantly influence transmittance and reflectance, with different trends observed for each optical response. This progressive characterisation highlights how cumulative fabrication decisions affect overall sensing performance. Luminance characterisation further indicates that successive manufacturing steps alter emitted light intensity, which is directly relevant to PPG signal quality.

Functional validation demonstrates that textile integrated optical sensing E-yarns are capable of extracting usable PPG signals in a transmittance mode configuration. Estimated PR and SpO_2 values show close agreement with reference measurements obtained from a commercially available pulse oximeter under resting conditions. These findings support the feasibility of garment integrated optical sensing for wearable cardiac function monitoring.

Conclusion

This work presents an optical sensor integrated textile platform enabled by E-yarn technology for wearable cardiac function monitoring. Through systematic optical characterisation across fabrication stages, the study demonstrates how encapsulation materials, textile braiding choices, and manufacturing parameters collectively shape optical behaviour and sensing performance. Validation through human trials confirms the capability of the platform to monitor PR and SpO_2 using a textile based transmittance mode PPG system. The outcomes provide design insights and methodological foundations for the development of textile integrated optical sensing platforms for real world wearable health and performance monitoring.

Textile-Compatible Connectors and Flexible Interconnects for Next-Generation Wearable Electronics.

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Introduction:

As wearable electronics increasingly migrate from rigid housings to garments and soft accessories, integrating electronic components directly into textile substrates has emerged as a critical challenge. Textiles are inherently flexible, deformable, and porous, whereas conventional electronic connectors and interconnects are typically rigid and mechanically incompatible. As a result, widely used solutions such as snap fasteners and rigid connectors often suffer from motion-induced noise, intermittent electrical contact, and reduced wearer comfort during prolonged use. These limitations are particularly problematic for wearable sensing systems, where signal stability and mechanical reliability are essential under dynamic conditions. Addressing this mismatch requires fabrication strategies that align electronic functionality with textile mechanics. In this work, a textile-compatible connector and interconnect integration strategy is introduced that utilizes embroidery-based fabrication for precise, flexible conductive routing and semi-rigid encapsulation to mechanically stable connectors while preserving stitchability. This approach aims to enable mechanically robust, electrically reliable interfaces suitable for scalable manufacturing of next-generation wearable electronic systems.

Materials and Methods:

Flexible interconnects were fabricated using 36 AWG copper wire embroidered directly onto a textile substrate (cotton-spandex interlock knit fabric) using a ZSK industrial embroidery machine. The embroidery process enabled precise routing, repeatable geometry, and secure mechanical anchoring of the conductive paths within the fabric. A commercial micro-HDMI connector was attached to a stitchable textile by covering its base with semi-rigid resin, which provided strain relief while keeping some flexibility at the connector–textile interface. The micro-HDMI pins were soldered to the embroidered copper interconnects, establishing a robust electrical interface. On the opposite end, the interconnects were terminated with textile-based electrodes through rivet-assisted soldering, providing secure mechanical and electrical connections. The assembled system was incorporated into an EMG armband to serve as a platform for performance evaluation. A control armband using conventional snap connectors was fabricated for comparative analysis.

Results and Discussion:

Both the embroidered-interconnect armband and the snap-based control armband were successfully fabricated, demonstrating the feasibility of integrating electronic connectors and interconnects directly within textile substrates. The embroidered 36 AWG copper interconnects exhibited good conformity with fabric deformation and remained securely anchored within the textile, indicating strong mechanical compatibility with wearable applications. Encapsulation of the micro-HDMI connector using a semi-rigid casting resin provided effective mechanical stabilization and strain relief at the connector–textile interface, a region commonly susceptible to fatigue and failure during repeated motion. Electrical continuity was consistently maintained across soldered joints at the connector and rivet-assisted soldered terminations at the textile electrodes, confirming reliable electrical integration. Although quantitative EMG signal testing has not yet been performed, the use of continuous embroidered copper pathways and a mechanically reinforced connector interface is expected to minimize contact intermittency and motion-induced artifacts. In comparison to conventional snap-based connectors, which rely on discrete contact points, the proposed approach is anticipated to offer improved signal stability and durability under dynamic wearable conditions.

Conclusion:

This study presents a scalable embroidery-based approach for textile-compatible connectors and flexible interconnects, enabling mechanically robust, stitchable integration with fabrics and offering a promising pathway toward improved durability, reliability, and performance in next-generation wearable electronic systems.

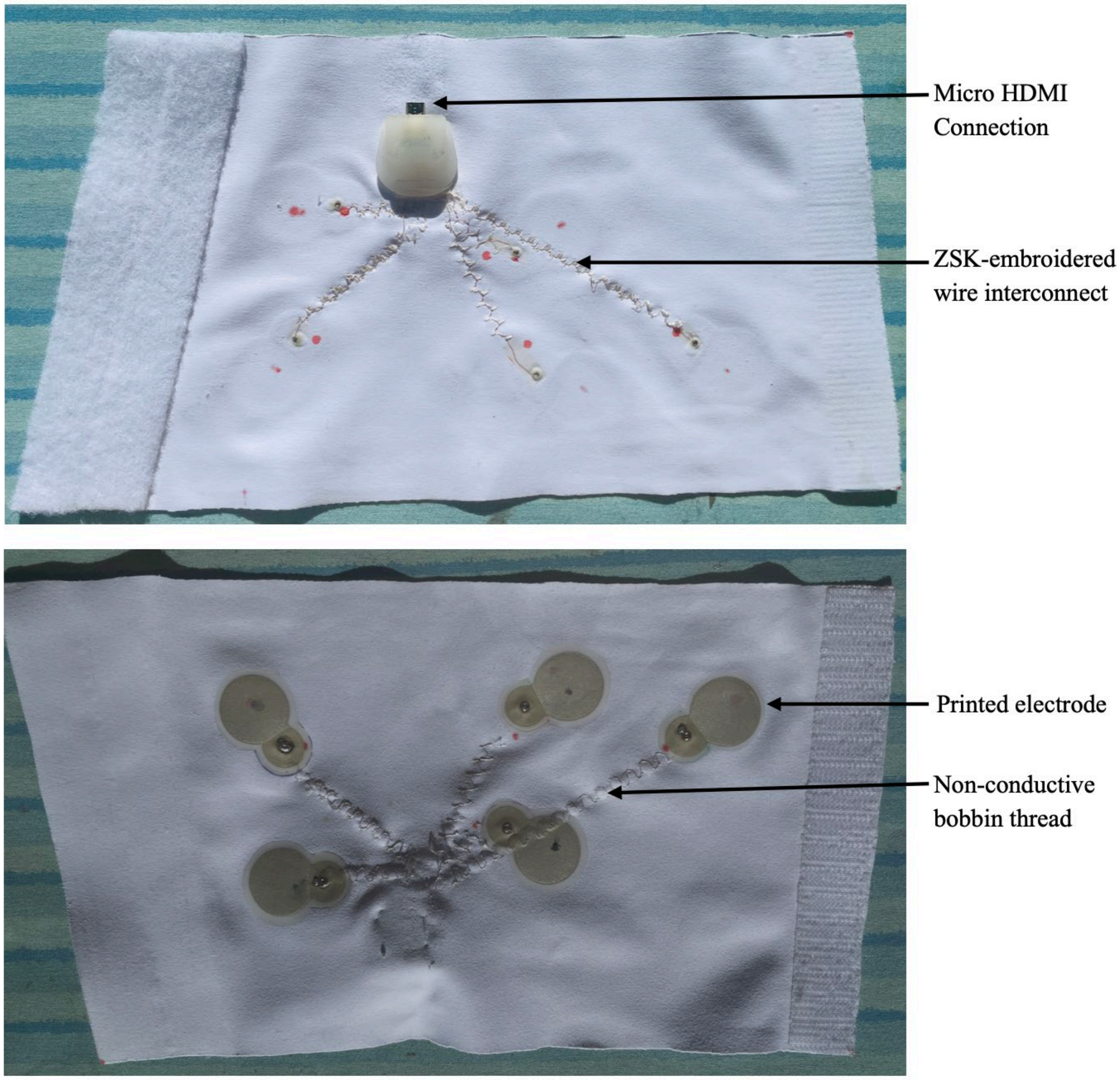

Figure: EMG armband with ZSK-embroidered wire interconnects and flexible connector

Smart Wearables for Muscular Chronic Pain Mitigation.

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Introduction:
Chronic pain is the primary cause of disability among adults in North America, surpassing heart disease, diabetes, and cancer in terms of its impact. It is estimated that one in five adults in the region experiences some form of persistent pain, with the shoulder and neck areas being the most common sites for these discomforts. This presentation will focus on the therapeutic effects of heat in alleviating muscle and joint pain through the process of vasodilation. When heat is applied locally, blood vessels expand as muscle cells relax, thereby improving blood circulation. This enhanced blood flow helps reduce pain associated with conditions like muscle tension and arthritis. Heat therapy presents a valuable alternative to oral pain medications, which have been linked to the opioid crisis and the overuse of non-steroidal anti-inflammatory drugs (NSAIDs), both of which carry significant health risks. Currently, patients often rely on cumbersome, uncomfortable heat packs that must be microwaved. Although heated jackets with battery-powered heating elements are used by athletes for long-duration comfort, they are typically designed to maintain body temperature and require bulky insulation to reduce heat loss. In contrast, effective heat therapy demands higher temperatures (ranging from 38°C to 66°C, depending on the method) and shorter treatment durations of 20 to 40 minutes.

Methods & materials:
To help people to cope with chronic pain on the go, we have developed a technological platform called MOBILE & COZY using electrothermal textiles. The prototype is a flexible heating scarf that comfortably covers the neck region, which is realized using conductive threads sewn along the synthetic felt substrate. The scarf is powered by a compact high-capacity Li-Ion battery, which together with an electronic control block can be either placed into an enclosure the size of a large cell phone for carrying inside a pocket or fully integrated into a scarf. The scarf bulk temperature reaches approximately 49^{o}C, a typical temperature used by infrared saunas to achieve a therapeutic effect. Finally, a compact 2-cell LiPo battery currently lasts approximately 25 minutes at the maximum output power.

Results & discussion:
During presentation we will discuss design principles of the therapeutic scarfs from the technological and clinical points of view, the first trials, as well as challenges when trying to commercialize them in the North American markets. Commercialization potential study of this technology was done within a Lab2Market program of the National Research Council of Canada (NSERC), while industrial prototypes were created in collaboration with Vestechpro Apparel Research and Innovation Center.

Conclusion:
Technology reported in this work can be helpful to people suffering from chronic pain, by reducing the discomfort of their daily tasks. It would also allow for discrete wear as our flexible textile heating technology can be easily integrated into traditional clothing items (ex. the heating scarf can be inserted into a fashionable scarf and worn as a part of an everyday outfit).

Evaluating Textile-Based Respiratory Sensors for Non-Invasive Monitoring: A Comparative Study Against Clinical Methods.

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Introduction

Chronic respiratory diseases affect over 569 million people worldwide and caused more than 4.2 million deaths in 2023 alone, making them a leading contributor to global morbidity and mortality.[1] Early detection and continuous monitoring of respiratory function are essential for preventing exacerbations in at-risk populations. Conventional respiratory assessment techniques, including auscultation, spirometry, pulmonary function testing, and polysomnography (PSG), are typically limited to clinical settings, short monitoring durations, and high costs. Wearable and textile-based sensing systems offer a promising, non-invasive, and cost-effective alternative by enabling continuous measurement of respiratory motion in clinical and real-world environments. This study presents a comparative evaluation of multiple wearable respiratory sensing modalities to identify the most effective approach for measuring respiratory features using clinical respiratory bands as the gold-standard reference.

Materials and Methods

Five respiratory sensing modalities were evaluated: a stretch sensor, a custom textile respiratory band with an integrated inductive sensor [2], an accelerometer, a TPU-based band provided by our collaborator[3], and clinical Compumedics respiratory bands. Five participants completed a structured breathing protocol with all sensors worn simultaneously, including shallow, normal, intense, and very intense breathing in 30-second intervals, followed by 30 seconds of breath-hold and 30 seconds of rest. The protocol was conducted in a sleep laboratory to allow direct comparison with the clinical gold standard. All signals were band-pass filtered (0.1–0.8 Hz), truncated to 390 seconds, and segmented into 30-second windows. Respiratory rate and depth were extracted using peak and trough detection, and agreement with the Compumedics bands was assessed using Pearson correlation and Bland–Altman analysis.

Results and Discussion

Comparative analysis revealed clear differences across sensing modalities. The textile respiratory band with an inductive sensor consistently showed the strongest agreement with the Compumedics bands, achieving high correlation and minimal bias for both respiratory rate and depth, including perfect correlation for side posture measurements ($r = 1.00$, $p = 0.0007$). The stretch sensor and accelerometer showed moderate correlations with increased variability across breathing intensities, while the TPU-based sensor demonstrated limited agreement for respiratory rate (near-zero correlations, e.g., $r = -0.02$, $p = 0.947$) and inconsistent performance for respiratory depth (e.g., $r = 0.62$, $p = 0.025$). Bland–Altman analysis further confirmed tighter limits of agreement and reduced bias for the textile band compared to other wearable modalities.

Conclusion

Our textile respiratory bands with integrated inductive sensors provided the most accurate and reliable measurements compared to stretch, accelerometer, and TPU-based sensors. We observe that sensor type, textile material, and how the textile conforms to the body critically influence performance in clinical settings. Careful design of both sensor and textile is therefore essential to ensure clinical reliability and long-term effectiveness of wearable respiratory monitoring systems.

References

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Balancing Delignification and Cellulose Integrity in Hemp-Derived Pulps for Regenerated Textile Fibres.

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Introduction:

The growing demand for low-impact textile fibres has intensified interest in alternative lignocellulosic feedstocks capable of supporting regenerated cellulose fibre production. Industrial hemp represents a promising candidate due to its high cellulose content and favourable agronomic profile; however, producing textile-grade pulp requires balancing effective delignification with preservation of cellulose molecular integrity. This study examines how pulping chemistry and processing conditions influence this balance in hemp-derived pulps intended for regenerated textile fibres.

Methods and Materials

Acid sulfite (AS) pulping was systematically evaluated using hemp bast and hurd feedstocks. Key processing variables, including pH, liquor-to-feed ratio, temperature, and pulping duration, were examined using a microreactor system that enables precise temperature control. Feedstock effects were further assessed by comparing mechanically disrupted and decorticated bast fibres. Pulp quality was characterized in terms of α-cellulose content, residual lignin, intrinsic viscosity (IV), and yield. For benchmarking, AS pulps were compared directly with soda-pulped hemp prepared under laboratory-scale alkaline conditions.

Results and Discussion

Across all conditions studied, AS pulping exhibited clear trade-offs between delignification efficiency and cellulose integrity. More severe conditions promoted lignin removal and apparent α-cellulose enrichment through preferential dissolution of non-cellulosic components, but resulted in substantial reductions in IV, consistent with cellulose chain degradation. Milder AS conditions preserved cellulose chain length more effectively but did not achieve lignin levels typically required for regenerated fibre processing, in particular for the lyocell process. Increasing the liquor-to-feed ratio modestly improved IV but did not significantly enhance delignification. Bast feedstocks outperformed hurd, yielding higher α-cellulose contents and lower residual lignin. Mechanically disrupted bast, while enabling more effective delignification, exhibited larger cellulose degradation than decorticated bast, reflecting increased fibre accessibility.

Comparison with soda pulping showed that alkaline processing achieved substantially lower residual lignin and higher intrinsic viscosity than AS pulping, despite lower overall yields. These findings highlight the limitations of AS pulping as a standalone route for producing hemp-derived pulps suitable for regenerated textile fibres. While AS pulps offered higher yields and increased cellulose accessibility, they did not simultaneously meet the combined requirements of low lignin content and sufficient cellulose molecular weight.

Conclusion
Overall, this work demonstrates that balancing delignification and cellulose integrity remains a central challenge in converting hemp into textile-grade regenerated cellulose. The results emphasize the importance of feedstock selection, pretreatment strategy, and pulping chemistry in determining pulp suitability for regenerated fibre applications and reinforce the continued importance of alkaline pulping pathways for textile-grade cellulose production.

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Toward sustainable air filtration: development of electrospun eco-responsible filtration media.

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Introduction
Filtration media play a critical role in personal protective equipment and collective ventilation devices. However, conventional filtration materials are commonly produced from petroleum-based polymers and rely on manufacturing processes associated with significant environmental impacts, including non-biodegradable waste and solvent-related emissions. In response to increasing sustainability requirements, the development of filtration media combining high protective performance with reduced environmental footprint has become a key challenge. Electrospinning has emerged as an attractive textile engineering technique for producing nanofibrous nonwoven structures characterized by high surface area, interconnected porosity, and enhanced particle capture efficiency. This study aims to develop eco-responsible electrospun filtration media and to investigate the relationships between processing parameters, structural characteristics, and filtration performance.

Methods and Materials
Electrospun filtration media were fabricated using a laboratory-scale electrospinning machine. Polylactic acid was selected as the polymer due to its biosourced origin and suitability for textile applications. Polymer solutions were prepared with less toxic solvent systems composed of cyclopentanone and dimethyl carbonate, chosen for their reduced health and environmental hazards compared with conventional electrospinning solvents.

For comparison, reference filtration structures were also electrospun from PLA solutions prepared with commonly used toxic solvents, including acetone and dimethylformamide. A response surface methodology was applied as the design of experiment to study the effects of key electrospinning parameters, namely applied voltage, solution flow rate, and tip-to-collector distance, while limiting the number of experimental runs from an eco-responsible perspective.

The resulting nanofibrous nonwoven media were characterized using scanning electron microscopy to evaluate fiber morphology and diameter distribution. Thickness and porosity were measured using standardized nonwoven testing methods. Filtration performance was assessed using sodium chloride aerosol particles to determine filtration efficiency and pressure drop on a laboratory-scale bench test.

Results and Discussion

Preliminary experiments performed on reference electrospun structures showed that a polymer concentration of 17.5 wt% enabled the formation of uniform and bead-free fibers at an applied voltage of 25 kV and a tip-to-collector distance of 20 cm. Under these conditions, the average fiber diameter was approximately (350 ± 90) nm, indicating suitable morphological uniformity for filtration applications.

Filtration tests demonstrated high particle capture efficiency, reaching approximately 99.99% at the most penetrating particle size (MPPS) of 300 nm. This performance was achieved with a low-pressure drop of around 10 Pa at an air face velocity of 15 cm/s, reflecting an excellent balance between filtration efficiency and airflow resistance. These results confirm the strong potential of the optimized reference structure as a baseline for process optimization. The response surface methodology analysis is currently ongoing to quantify the individual and interaction effects of electrospinning parameters on structural and filtration properties.

Conclusion

This study confirms the relevance of electrospinning as a textile engineering approach for the development of functional PLA-based nanofibrous filtration media. The preliminary results highlight the key role of fiber morphology and nonwoven architecture in achieving high filtration performance with low airflow resistance. Ongoing statistical optimization will further support the design of sustainable filtration textiles for protective and technical applications.

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Experimental Evaluation of Combustion-Derived Contaminant Deposition on Flame-Resistant Fabrics Used in Wildland Firefighting.

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Wildfires have increased in both frequency and severity across the United States over the past two decades. These large-scale fire events pose significant threats to ecosystems, infrastructure, and human health. Wildland firefighters play a critical role in mitigating wildfire spread and protecting communities, yet they are repeatedly exposed to hazardous combustion products during suppression activities. Unlike structural firefighters, wildland firefighters operate for extended durations in close proximity to open biomass combustion, often under high thermal and physical stress, raising concerns about chronic occupational health risks.

In wildland firefighting, combustion of vegetation materials generates a complex mixture of carcinogenic compounds, including polycyclic aromatic hydrocarbons (PAHs) and other organic species. These compounds can deposit on or penetrate through the fabrics used in wildland firefighters' protective clothing, leading to dermal exposure. Study result shows that firefighters experience ~ 9% higher incidence of cancer compared to the general population, highlighting the need for improved understanding of exposure pathways. To enhance protective strategies for wildland firefighters, it is essential to investigate how fabric properties influence the deposition and transmission of combustion-derived contaminants.

This study examines the effects of fabric structure and surface characteristics on the deposition of wildfire-generated contaminants. Three commercially available flame-resistant outer shell fabrics commonly used in wildland firefighting ensembles, along with one inner-layer fabric, were selected for evaluation. Fabric surface properties, including surface friction and surface roughness, were characterized using the Kawabata Evaluation System, while air permeability was measured using a standard air permeability tester in accordance with established testing protocols.

A novel laboratory-based exposure methodology was developed to generate controlled combustion environments. Combustion-derived contaminants were produced by burning wood in a controlled chamber. Fabric specimens were exposed to combustion products for 20 minutes under two burning temperatures (400 °C and 600 °C) and two airflow conditions (0.5 L min^{-1} and 1.0 L min^{-1}). Following exposure, contaminant deposition on fabric surfaces was quantified.

Results indicate that both combustion temperature and airflow rate significantly influence contaminant deposition. Higher burning temperatures and increased airflow resulted in greater deposition on fabric surfaces. Fabrics with lower air permeability captured a higher quantity of contaminants compared to more permeable fabrics, suggesting restricted airflow enhances particle and vapor retention. Additionally, surface friction and surface roughness exhibited positive correlations with contaminant deposition, indicating that micro-scale surface interactions play a critical role in contaminant capture.

Deposited contaminants were extracted and analyzed using gas chromatography–mass spectrometry (GC–MS). Identified compounds included phenolic, ketonic, and other hydrocarbon species, many of which are associated with carcinogenic or toxicological effects in humans. These findings confirm that wildfire-generated contaminants can accumulate on protective fabrics in chemically hazardous forms.

In conclusion, this study demonstrates that fabric structural and surface properties substantially influence the deposition of combustion-derived contaminants relevant to wildland firefighting. Improved material selection and multilayer system design may reduce dermal exposure to carcinogens, thereby enhancing long-term occupational health protection for wildland firefighters.

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Manufacturing Flame-Resistant Lyocell Fibre from Flame-Resistant Cotton Waste Fabrics through Optimized Pulping Process.

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Introduction

This research investigates the use of flame-resistant (FR) cotton waste fabric to produce regenerated cellulose fibres via the lyocell process. The study focuses on optimizing pulping strategies to control the degree of polymerization (DP), reduce transition metal content, and retain phosphorus-based FR functionality in pulp and subsequent extruded fibres.

Methods & Materials

The feedstock was a navy-blue, 100% cotton FR fabric used for oil and gas industry coveralls. The fabric contained 98 ± 3% α-cellulose with no detectable hemicellulose or lignin. After standardized washing (ISO 6330) and shredding, two pulping pathways were investigated: sulfuric acid hydrolysis and stepwise chelation without hydrolysis. Acid hydrolysis was optimized by varying acid concentration (0.5–3.0%), temperature (70–90 °C), and treatment time (30–120 min). Chelation strategies explored included EDTA-based systems, EDTA/SHMP combinations, and N-methylmorpholine-N-oxide (NMMO)-assisted treatments. Intrinsic viscosity was measured according to ASTM D1795-13. Metal and phosphorus contents were quantified by Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES). Optimized pulps were dissolved in a 50% NMMO–water solution, and fibres were spun following the dry-jet wet spinning method using a laboratory setup without drawing. Fibre morphology, crystallinity, and phosphorus retention were evaluated using optical microscopy, X-ray diffraction (XRD), and ICP-OES respectively.

Results & Discussion

Acid hydrolysis reduced the degree of polymerization and lowered the transition metal content. Hydrolysis yield remained high (95–97%) across all conditions. However, reducing iron levels below the 10 ppm threshold required harsh conditions that caused excessive degradation of the cellulose chains. On the other hand, a sequential chelation approach combining EDTA/SHMP pre-treatment with repeated 50% NMMO–water cycles reduced iron content almost to the recommended threshold while preserving polymer integrity, maintaining an intrinsic viscosity within the recommended range. Dissolving pulps produced using optimized conditions with both strategies yielded continuous, flexible fibres with uniform morphology. XRD analysis confirmed the transformation from Cellulose I to Cellulose II, verifying successful regeneration. The crystallinity index of the fibres (≈35–36%) was lower than that of commercial lyocell fibres, primarily due to the absence of a drawing step in the lab-scale spinning process. Importantly, phosphorus content was largely retained throughout pulping and spinning, reaching 14,300 - 18,200 ppm in the regenerated fibres, well above levels typical of conventional FR regenerated cellulose, indicating strong potential for FR protective fabrics without extensive post-finishing. Minimal dye bleeding was observed, suggesting that colour retention may eliminate the need for re-dyeing if colour-sorted feedstocks are used.

Conclusion

This study demonstrates that FR cotton waste is a viable and high-value feedstock for lyocell fibre production. By balancing DP control and metal removal through optimized hydrolysis and chelation strategies, regenerated fibres with preserved FR functionality and acceptable structural characteristics were produced. The results highlight a promising circular pathway for recycling technically finished cotton textiles, with potential reductions in chemical use, processing steps, and environmental impact. These findings are relevant for advancing sustainable fibre manufacturing and circular textile systems.

Improving Charge Stability in PLA Meltblown Electret Filters.

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Introduction

Electret meltblown nonwoven filters use stored electrostatic charges to capture particles efficiently while maintaining a low pressure drop. Polypropylene (PP) is commonly used for this purpose because of its stable crystalline structure and strong ability to retain charge. However, growing interest in sustainable materials has led to increased attention on polylactic acid (PLA) as a bio-based and industrially compostable alternative. Although PLA offers clear environmental benefits, it tends to lose its electrostatic charge more quickly, which limits its long-term filtration performance. This rapid charge decay is mainly associated with PLA's lower crystallinity and smaller interfacial area between crystalline and amorphous regions, where deep charge traps are typically formed. As a result, fewer deep charge traps are available to retain charges over time. This study explores the use of nucleating additives to modify the crystalline structure of PLA and examines how these changes influence filtration performance and charge stability in meltblown electret filters.

Materials and Methods

PLA 6100D and PP 3155 (35 MFI) were processed into meltblown nonwoven webs using the Biax meltblown line at The Nonwovens Institute. All samples were produced with a similar basis weight of approximately 30 g/m^2. $BaTiO_3$ was incorporated at concentrations of 0.5%, 1%, and 2%, with neat PLA and PP serving as control samples. All samples were charged using a corona charging system at −30 kV on both sides. Filtration efficiency and pressure drop were measured following standard test methods, and the quality factor was calculated to evaluate overall filtration performance. Crystallinity was analyzed using differential scanning calorimetry (DSC), while fiber morphology and web structure were examined using scanning electron microscopy (SEM). X-ray diffraction (XRD) was used to evaluate crystalline structure and estimate crystal size. Accelerated aging tests were conducted according to ASTM F1980-21, with PLA samples aged at 50 °C to remain below their glass transition temperature and PP samples aged at 60 °C, both at 20% relative humidity, for a period of nine weeks.

Results and Discussion

For both PLA and PP, charged samples consistently exhibited higher filtration efficiency compared to uncharged controls. Increasing $BaTiO_3$ concentration resulted in a reduction in filtration efficiency and pressure drop for both polymers; however, the quality factor remained nearly constant or showed a slight improvement due to the reduced airflow resistance. DSC results indicated that crystallinity of PP remained largely unchanged with increasing $BaTiO_3$ content, while PLA showed fluctuations in crystallinity without a clear monotonic trend. SEM analysis revealed no significant processing instability or fiber degradation associated with $BaTiO_3$ addition in either polymer. Aging results demonstrated improved charge retention behavior in PLA samples containing $BaTiO_3$ compared to neat PLA, with selected formulations maintaining higher filtration efficiency over the aging period. These observations suggest that $BaTiO_3$ may be effective in enhancing charge stability in PLA-based electret filters.

Conclusion

The results indicate that $BaTiO_3$ is a promising additive for PLA meltblown electret filters, offering acceptable filtration performance while maintaining or improving quality factor. Unlike conventional additives that can negatively impact PLA process ability, $BaTiO_3$ demonstrated good compatibility with both PLA and PP. Ongoing work focuses on detailed analysis of additive concentration effects to further optimize sustainable electret filtration media.

Graphene-based electrospun sensor for low strain sensing applications.

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Abstract

The rapid progress in advanced functional materials has greatly influenced the development of sensing technologies for structural health monitoring (SHM), enabling the emergence of intelligent and responsive structures. Graphene-based sensors offer notable advantages, including high strain sensitivity, excellent flexibility, and the ability to monitor multiple physical parameters. This study investigates the fabrication and performance of conductive graphene ink films designed for low-strain sensing. The conductive films are fabricated using the electrospinning technique, and their morphology, electrical behaviour, and gauge factor were evaluated. The influence of different strain rates on sensor performance was also examined. Across all conditions, the gauge factor was found to range between 10.2 and 11.3. Furthermore, cyclic bending tests confirmed the consistency and reliability of the sensors, showing minimal signal drift and stable gauge factor values under repeated loading. The findings demonstrate that graphene ink films provide a lightweight, energy-efficient, and non-intrusive solution for low-strain monitoring, with strong potential for applications in SHM and wearable electronics.

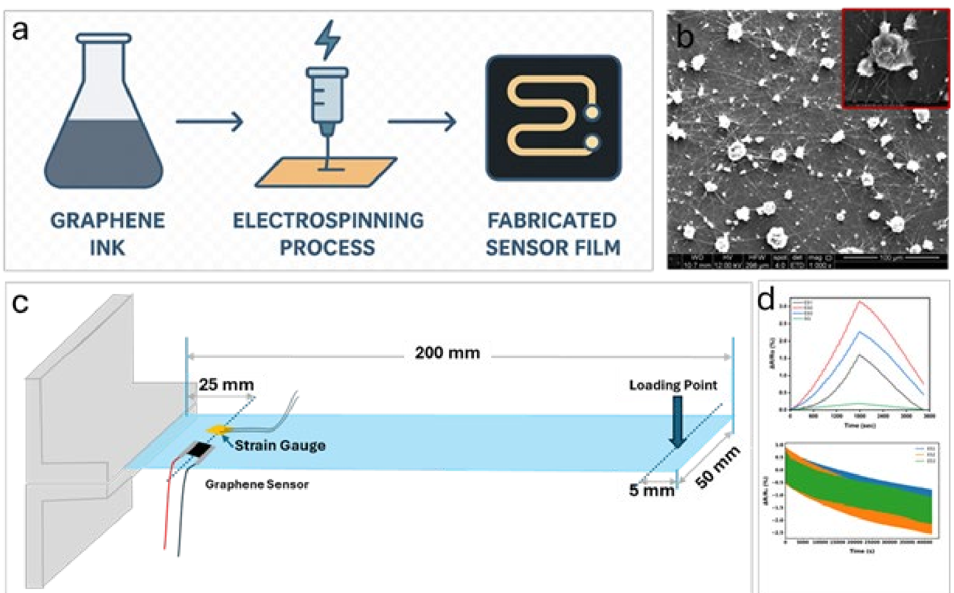

Figure 1: (a) Electrospun conductive film fabrication process, (b) Surface morphography (SEM), (c) Experimental process, (d) Electromechanical test results.

Automated Morphological Characterization of Recycled Cotton Textiles for Loose-Fill Insulation Production via Optical Microscopy and Computer Vision.

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The building sector represented 31% of the global CO2 emissions in 2019. Within this sector, half of the emissions were related to energy usage from residential buildings, with the majority of the energy demand used for space heating in North America, Europe and Eurasia[1]. As part of the efforts to reduce emissions, insulation materials may play a role toward increased energy savings[1,2]. In this context, recycled post-industrial waste from the textile and clothing industry, a sector accounting for 8–10% of global emissions[3], has been investigated as an option for building insulation. While research on recycled textile insulation has focused on structured shapes such as those provided by nonwovens[4,5] and composites[6–8], a recent investigation has shown a simpler approach based on cotton loose-fill insulation[9]. Building on this, we examine the feasibility of using computer-aided image analysis to characterize the morphology of these processed materials.

The present study investigated three mechanical processing conditions for recycling post-industrial cotton textile off-cuts: shredding, knife milling, and a combination of both. The methodology focused on a digital image analysis workflow based on optical microscopy. A comparative approach was adopted: ImageJ software was used to determine size distributions and distinct output fractions, while a custom computational script utilizing the Segment Anything Model (SAM 2) was developed to explore the automated detection of individual, non-overlapping fibers.

Initial results indicated that the processing technique affected the final morphology of the samples. The ImageJ analysis allowed the quantification of three different morphologies: small textile fragments, yarns, and fibrous aggregates. Shredding yielded a composition consisting primarily of long yarns, followed by fibrous aggregates and a smaller amount of unopened textile fragments. In contrast, the knife mill process produced a higher proportion of small textile fragments while reducing both the quantity and average length of the yarns. Subsequent processing of the shredded material via the knife mill further reduced the average size and proportions of the different morphologies. Regarding the automated workflow, the SAM algorithm demonstrated the ability to detect individual fibers and distinct shapes. However, the preliminary segmentation results highlighted specific challenges in separating overlapping fibers, which hindered the accuracy of the automated dimensional measurements.

These preliminary results indicate that the chosen mechanical processing technique significantly influences material morphology. Regarding characterization, the study suggests that computer vision tools like SAM offer a promising pathway for the rapid, automated quality control of recycled textiles for insulation. Future work will focus on refining the segmentation parameters to improve the distinction of overlapping fibers and calibrating the automated dimensional measurements. This development is an important step to enable the scalable characterization of sustainable insulation materials.

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Smart Textile for Non-Invasive Core Body Temperature Estimation During Exercise.

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Introduction

Monitoring core body temperature is a critical physiological parameter for optimizing athletic performance and ensuring safety in extreme occupational environments. While ingestible telemetric pills provide accurate core measurements, their high cost and single-use nature limit widespread adoption. Consequently, there is significant interest in wearable smart textiles that estimate core temperature through non-invasive skin measurements. However, single-point skin readings often fail to capture complex, region-specific thermal dynamics during exercise, where blood flow and perspiration cause localized warming or cooling. This study evaluates the validity of a multi-site e-textile system equipped with distributed sensors to provide a holistic thermal profile of the body during physical activity.

Materials & Methods

The smart textile consists of cotton-elastane blend. We used flexible temperature sensor in our developed garment and used conductive yarns to connect the microcontroller. The primary study includes healthy adult participants, participated in a 40-minute treadmill protocol comprising warm-up, jogging, peak exercise, and cooldown phases. An ingestible temperature pill was used to get participants core body temperature. Statistical analysis was performed to analyze the results.

Results & Discussion

Results indicated substantial differences between skin and core temperatures, with mean absolute error (MAE) values ranging from 8.3°C to 9.9°C across sites. The Right Upper Arm emerged as the most reliable as exhibited the highest consistency and correlation across participants ($r = 0.55–0.78$) and the lowest average errors (MAE ~8.3°C), so far. While core temperature remained relatively stable (37–38°C), skin temperatures converged toward the core as exercise progressed, narrowing the gradient from ~11°C at baseline to 5–10°C by the end of the session. However, arm sites occasionally overshot core temperatures during high-intensity phases, likely due to convective heat transfer from the core to the periphery and regional vasodilation. The use of cotton fibers may have influenced these local effects, as their lower evaporative efficiency compared to synthetic wicking fibers can increase local humidity and thermal capacitance at the skin-fabric interface.

Conclusion

This study demonstrates the feasibility of real-time thermoregulation monitoring using distributed flexible temperature sensor integrated into a garment. The findings prioritize the upper arm as a key sensing zone due to its stable perfusion and consistent microclimate. The ongoing work focuses on optimizing garment design by adopting special fiber blends to improve moisture wicking and adding sensing locations to enhance the accuracy of core temperature estimation models.

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A Systematic Review of Sensing Modalities and Integration Challenges in Textile-Based Sweat Lactate Monitoring.

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Introduction:

The rising prevalence of chronic conditions in an aging global population necessitates a paradigm shift from reactive healthcare to proactive, continuous monitoring. Sweat lactate, a key metabolic biomarker, offers a non-invasive window into physiological status; however, its effective integration into textile-based wearables remains technically challenging. This systematic review evaluates the current state of textile lactate sensors, aiming to identify the engineering barriers—specifically regarding durability and sensing modality—that currently prevent the transition from academic prototypes to reliable clinical tools.

Materials and Methods:

We conducted a systematic search across PubMed, Web of Science, and Scopus covering the period from January 1, 2020, to December 31, 2025. Adhering to PRISMA guidelines, studies were selected based on the PICO framework. We included wearable devices where textile acted as a functional component (substrate or sensing interface) for lactate monitoring. From an initial pool of records, 30 studies met the inclusion criteria. Data were extracted regarding transduction mechanisms (Enzymatic vs. Optical), power sources, fluidic management, and standardized performance metrics such as washability.

Results and Discussion:

The analysis reveals a fragmented landscape characterized by a trade-off between specificity and durability. Enzymatic sensors dominate the field (80%), offering high selectivity but suffering from biological instability and limited shelf-life. Conversely, optical methods like Surface-Enhanced Raman Scattering (SERS) (13%) offer superior sensitivity and stability but rely on bulky external readout instrumentation, limiting their wearable utility. Crucially, a significant integration gap was identified: while 90% of reviewed solutions aimed for reusability, only 19% underwent rigorous washability testing. Additionally, recent innovations show a shift toward "Janus" structure fabrics for unidirectional sweat transport and autonomous powering via Near Field Communication (NFC) or the use of biofuel cells to eliminate rigid batteries.

Conclusion:
Current textile-based lactate sensors are functionally stalled at the stage of disposable patches rather than realizing reusable smart clothing. While sensing technologies are mature, the lack of standardized washability protocols and on-body correlation with blood lactate or ventilatory thresholds, prevents clinical adoption. Future development must prioritize energy autonomy and robust durability testing to enable scalable, proactive health monitoring.

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Revaluing Waste Wool: Exploring Sustainability Through Felting and Thinking-Through-Making.

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Introduction / Conceptual Framework
This project investigates how hands-on, material-led experimentation can open new possibilities for sustainable textile design. Drawing on Tim Ingold's (2013) concept of thinking through making, the study positions craft processes as generative forms of knowledge, where understanding emerges from direct engagement with fibres, tools, and embodied action.

The research focuses on wasted fleece from the skirting process, a category of undesired wool commonly discarded due to excessive vegetable matter, dirt tips, off-colored, felted or matted (Barker & Barber, 2009, pp. 109–114, Robson & Ekarius, 2011, p. 27). Inspired by sustainability practitioners who advocate for revaluing agricultural waste (Earley, 2017), this project asks:

- How can waste fleece be transformed into meaningful textile material?
- What can felting experiments reveal about the hidden value of "unwanted" fibres?
- How can creative practice contribute to conversations about Ontario's wool sustainability challenges?

Creative Practice / Methods
The project uses an iterative, hands-on creative research methodology, including:

- **Fibre Sorting & Material Preparation**
    - Collected skirted fleece from local farms
    - Categorized the fleece by condition:
        - Locks with dirt tips
        - Areas with high vegetable matter
        - High crimp, short staple
- **Wet Felting Experiments**
    - Layered sorted fleece into felt sheets
    - Explored density, texture, and randomness created by VM and staple variation
    - Conducted preliminary felting tests using raw (unwashed) fleece to assess whether post-felting washing could reduce water use
    - Documented process photographs, weight, thickness, and shrinkage
- **Material Iteration & Prototype Development**
    - Created irregular, sculptural felt textiles
    - Tested strength, flexibility, and surface expression
    - Conducted initial tests attaching felted samples to muslin

This practice-based approach embraces the unexpected, allowing the irregular behaviour of waste fibre to shape the outcome

Results / Discussion

1. Waste Wool Has Hidden Material Potential

Waste fleece, often deemed unusable, forms dense, visually rich felt with structural integrity. VM contributes unexpected colour, texture, and narrative value.

2. Thinking-Through-Making Generates New Understanding

Fibre behaviour (clumping, migrating, resisting) taught more about the material's capability than theoretical research alone. Making became a method of knowing.

3. Sustainability is Embodied and Relational

Working directly with a "waste" material fosters empathy for farmers, the shearing process, and local fibre systems. Material engagement reshapes what counts as "valuable."

4. Design Opportunities Exist in Imperfection

Irregular felt surfaces suggest future uses for accessories or protective textiles. The imperfections, historically dismissed, become aesthetic features.

Conclusion / Implications

This exploratory study demonstrates that waste wool can be transformed into expressive, structurally sound textile prototypes through simple, low-impact processes. By repositioning discarded fleece not as waste but as a resource, the work highlights how creative practice can contribute to sustainable material conversations in Ontario's wool ecosystem.

Future steps include combining the felt with muslin to create knitting pouches that celebrate the material's origin.

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Electronic Textile Platforms for Cardiorespiratory Monitoring: Integration Strategies, Signal Performance, and Clinical Validation.

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Introduction

Electronic textiles (e-textiles) integrate conductive and sensing elements directly into garments, offering a promising pathway toward continuous, unobtrusive cardiorespiratory monitoring. Unlike conventional gel electrodes and rigid wearables, textile-based systems can be worn as everyday clothing, potentially improving comfort, adherence, and long-term usability. Rapid advances in conductive materials, textile manufacturing, and integration strategies have enabled the acquisition of physiological signals such as electrocardiography (ECG) and respiration using garment-based platforms. However, translation into clinically relevant tools remains limited by motion artifacts, garment fit sensitivity, durability concerns, and heterogeneous validation practices. This review synthesizes recent experimental evidence to identify defensible material and integration choices for textile-based cardiorespiratory monitoring.

Materials & Methods

A narrative review with a structured search strategy was conducted across PubMed, IEEE Xplore, and Google Scholar. Keywords targeted textile-based wearables, flexible biomedical sensors, and cardiorespiratory monitoring. Approximately 180 records were identified, with 52 articles retained for full-text review. Twenty-five primary experimental studies met inclusion criteria, focusing on textile-based systems with physiological validation for ECG and/or respiration. Studies using non-textile or rigid form factors, lacking physiological validation, or addressing non-cardiorespiratory outcomes were excluded. Material families, integration approaches, physiological targets, and validation metrics were extracted and compared to assess performance trends and translational readiness.

Results & Discussion

Three dominant conductive material families were identified: metallic conductors (especially silver-coated yarns), carbon-based conductors (e.g., graphene, carbon nanotubes, carbon black composites), and conductive polymers (notably PEDOT:PSS). Metallic yarn electrodes integrated through knitting or embroidery most consistently supported high-quality ECG waveform acquisition under resting or low-motion conditions, owing to high conductivity and compatibility with established textile processes. However, their performance frequently degraded with motion due to contact instability and impedance fluctuations. Carbon-based composites and conductive polymers offered greater mechanical compliance and wearer comfort, making them well suited for deformation-based respiration sensing, but exhibited variable conductivity, durability, and wash stability across formulations. Hybrid systems aimed to balance these trade-offs but remain underrepresented in long-duration and free-living studies.

Across physiological targets, ECG monitoring is the most mature application in controlled settings, while respiration sensing using strain- or deformation-based textile elements is often more tolerant to everyday motion for estimating respiratory rate. A major cross-cutting limitation is inconsistent validation: many studies rely on correlation metrics without agreement-focused analyses, use small homogeneous cohorts, and evaluate only short laboratory tasks. These practices limit clinical interpretability and comparability across systems.

Conclusion

Current evidence supports metallic yarn-based ECG systems for waveform-focused monitoring in controlled or supervised contexts, and polymer/composite-based systems for comfort-oriented respiration monitoring. However, motion artifacts, fit dependence, durability, and non-standardized validation remain primary barriers to translation. Progress toward clinical relevance will depend less on novel materials and more on disciplined system-level evaluation, including agreement-based metrics, transparent reporting of data loss and failure modes, testing under representative activities, and larger, more diverse cohorts. Aligning material choices and validation endpoints with intended use cases is essential for advancing electronic textiles from feasibility demonstrations to clinically meaningful monitoring tools.

Comfort-Oriented Wearable ECG Garment: Textile Electrode Performance for Heart Rate Accuracy and Waveform Fidelity.

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Introduction

Wearable electrocardiography (ECG) technologies are increasingly used for continuous physiological monitoring in clinical and home environments. While conventional gel-based electrodes provide high-quality signals, they can be uncomfortable and impractical for long-term wear. Textile-based electrodes integrated into garments offer a promising alternative by improving comfort and usability, but must demonstrate both accurate heart rate (HR) estimation and preservation of ECG waveform morphology to be clinically relevant. Agreement in R-peak timing alone does not ensure signal fidelity, as variations in skin–electrode contact and garment mechanics can distort morphology without preventing peak detection. This study, therefore, evaluates a wearable textile ECG system using both HR agreement and waveform-level similarity analysis.

Materials & Methods

A custom stretchable garment was developed, integrating sewn silver-coated knitted textile electrodes (Shieldex® P130B) with snap-button connectors. Each electrode provided ~15 cm^2 contact area and was supported by a nonwoven backing to improve contact stability. Ten healthy adults participated in a controlled laboratory study (UHN REB approved). Simultaneous ECG recordings were obtained from textile electrodes and clinical gel Ag/AgCl electrodes (reference) using a Compumedics GRAEL PSG system at 512 Hz while participants lay supine. Signals were bandpass filtered (0.5–50 Hz). HR was derived from R-peaks using 30-second sliding windows. Waveform similarity was quantified using Dynamic Time Warping (DTW) on short, amplitude-normalized ECG windows, with normalized DTW distance used as a morphology similarity metric. Pearson correlation and Bland–Altman analysis assessed HR agreement, and DTW values were summarized per participant.

Results & Discussion

Textile-derived HR showed very strong agreement with gel-based ECG ($r = 0.99$, $p < 0.001$), with a mean Bland–Altman difference of 0.29 bpm, indicating low bias and narrow limits of agreement under baseline supine conditions. Normalized DTW distances were low across participants (median 0.00260, IQR 0.00154–0.00331), demonstrating high waveform-level similarity between textile and reference ECG. Participants with slightly higher DTW values exhibited localized waveform distortions and baseline fluctuations, highlighting DTW as a sensitive indicator of skin–electrode interface stability. Lower DTW values generally corresponded to smaller HR errors, though moderate morphology distortions did not always translate to large HR deviations, reinforcing the complementary roles of HR and waveform metrics. The stretchable garment design supported consistent skin contact, but results underscore the importance of garment fit and mechanical coupling. Unlike gel electrodes that rely on adhesives, textile electrodes depend on sustained mechanical contact, making interface stability critical for minimizing artifacts. These findings confirm that textile electrodes can preserve ECG morphology sufficiently for reliable R-peak detection and downstream analyses such as HR variability and ECG-derived respiration under controlled conditions.

Conclusion

The developed textile ECG garment demonstrated accurate baseline HR estimation and strong waveform-level agreement with clinical gel electrodes. DTW-based morphology analysis provided additional validation beyond rate metrics, confirming preservation of ECG waveform shape. While promising for comfortable, continuous monitoring, further work is needed to optimize the skin–electrode interface, connector design, and durability, and to validate performance in ambulatory, real-world settings with greater motion and environmental variability. Textile-based ECG systems represent a viable pathway toward long-term, user-friendly cardiac monitoring when morphology-level fidelity is maintained.

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Insights into the Persistence of Florine-Containing Finishes on Fire Protective Fabrics.

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Introduction

Firefighter protective garments are designed to meet the required performance levels to allow firefighters to perform their duty as safely as possible. They combine fabrics made with high-performance fibres with water and oil-repellent finishes. These finishes typically rely on fluorocarbon-based chemicals to provide the required high level of water and oil repellency. Over time, the performance of water-repellent finishes can degrade for several reasons, such as abrasion, laundering, and exposure to UV light. For instance, Bates et al. (2025) revealed a total loss in water repellency of outer shell fabrics used in firefighter bunker suits after 50 cycles of commercial laundering. Given the policy changes currently implemented to limit the use of fluorocarbon-based finishes, a study was conducted to determine the amount of residual fluorine in fabrics when water repellency has disappeared due to service conditions.

Material and Method

Five commercially available firefighter outer shell fabrics were selected based on clear evidence of a fluorocarbon-based water-repellent finish. These five fabrics covered different fibres contents and included para-aramid, meta-aramid, polybenzoxazole (PBO), polybenzimidazole (PBI), and liquid-crystal polyester (LCP) fibres. Chemical composition analyses were performed by energy-dispersive X-ray spectroscopy (EDX) to measure the fluorine content on the fabric surface in the original state and after 30 and 50 wash cycles. These laundering cycles had been carried out by a commercial laundering facility specialising in turnout gear (Innotex, QC, Canada). After the 50 laundering cycles, all fabrics had lost their water repellency (Bates et al., 2025).

Results and discussion

The initial fluorine content on the surface of the fabrics varied between 4.32% and 1.66% depending on the fabric. All the fabrics showed a reduction in the fluorine content with increasing number of laundering cycles. However, the level of reduction varied with the fabric, ranging from 28% to 78% after 50 laundering cycles. In addition, the level of reduction in the fluorine content after 50 laundering cycles was not correlated with the initial fluorine content on the fabric. Finally, none of the fabrics demonstrated the complete removal of fluorine from the fabric surface after the 50 laundering cycles despite their complete loss in water repellency: the residual fluorine content after 50 laundering cycles ranged between 0.5 and 2.23%.

These results show that the residual water repellency of a fabric cannot be used as an indicator of its residual fluorine content. As the depth of material analysis via EDX is 1 to 5 µm, this indicates that the water-repellent finish penetrates into the thickness of the fabric.

Conclusion

This study shows that five fabrics that underwent commercial washing and completely lost their water-repellent properties after 50 laundering cycles retained a significant amount of fluorine. It confirms that the residual water repellency of a fabric cannot be used as an indicator of its residual fluorine content.

Reference

Bates B., Hoque Md. S., Munevar-Ortiz L., Batcheller J., Dolez P. I. (2025). Effect of Different Laundering and Drying Procedures on the Performance of Fire-Protective Fabrics. Journal of Polymer Science. 63(16), 3496-3508

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From Hemp Bast to Lyocell Fibre: Optimization of Dissolving Pulp Preparation.

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Introduction

The growing demand for sustainable cellulose textile fibres has prompted the exploration of non-wood feedstocks and environmentally friendly pulping processes. Canadian hemp bast fibre offers high α-cellulose content (~74%) with low hemicellulose (~9.8%) and lignin (~3.1%), which makes it a promising candidate for lyocell fibre production. This study aims to develop and optimize a simplified, more sustainable pulping process to produce high-purity dissolving pulp suitable for lyocell manufacturing.

Materials and Methods

Hemp bast fibre from the cultivar Anka (Bruderheim, Alberta, 2023) was processed using a sequential combination of alkali treatment, mild chelation, and totally chlorine-free (TCF) alkaline hydrogen peroxide (H2O2) bleaching. Preliminary tests had shown that the pre-hydrolysis step of the conventional pre-hydrolysis kraft (PHK) process was not necessary to achieve the target lignocellulosic content due to the inherently low hemicellulose content of hemp bast fibre. It was thus omitted. The optimized alkali treatment employed 5 wt% sodium hydroxide at 170°C for 60 min. Chelation used low concentrations of two chelating agents, EDTA and SHMP (0.2 wt% each, 60°C, 20 min). Bleaching was conducted with 2 wt% H2O2 at 80°C for 20 min.

Pulp samples were analyzed for α-cellulose, hemicellulose, lignin, ash, extractives, intrinsic viscosity, and metal content by using standard testing methods. Lyocell fibre morphology was examined by scanning electron microscopy (SEM), and the cellulose crystalline structure was analyzed using X-ray diffraction (XRD). Cumulative yield was calculated across all processing stages. Dissolving pulp was dissolved in aqueous N-methylmorpholine N-oxide (NMMO) to form spinning dope, which was spun into lyocell filament in lab-scale and prototyping dry-wet spinning lines.

Results and Discussion

The optimized process produced pulp with ~97% α-cellulose, 3.3% hemicellulose, <0.1% lignin, and an intrinsic viscosity of 3.05 ± 0.04 dL/g. Transition metals were reduced below 10 ppm, and alkali/alkaline earth metals below 100 ppm, meeting lyocell-grade purity standards. Cumulative yield reached 63.7%, 21 percentage points higher than typical wood-based PHK pulping (42.5%, reported in literature).

Lab-scale spinning produced continuous hemp-based lyocell fibres with smooth surfaces, uniform cross-sections, and regenerated cellulose II structure. Crystallinity index (~38%) reflected the undrawn fibre morphology. The pulping process was successfully scaled up for the preparation of 1L of spinning dope, which was successfully processed in the prototyping spinning line. It yielded a fibre with a regular diameter.

Conclusion

Canadian hemp bast fibre is a highly suitable and sustainable feedstock for lyocell fibre manufacturing. The developed alkali-chelation-bleaching process efficiently purifies hemp pulp to lyocell-grade standards. This process eliminates sulphur and chlorine chemicals, reduces chemical consumption, and lowers environmental and health hazards while preserving cellulose integrity and yield. Successful bulk-scale dope preparation and prototyping spinning demonstrate industrial feasibility. This approach provides a cleaner, cost-effective, and scalable route for non-wood cellulose fibre production, contributing to bridging the global cellulose gap.

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Photocatalytic Activity of UV-Assisted $CuBi_2O_4$ Nanorods.

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Introduction:

Metronidazole is a widely used antibiotic. It can persist in the environment, for example entering water through wastewater streams. Common treatment steps may not fully remove it. As a result, it can be a threat to human health and ecosystems due to its toxicity and potential to induce bacterial resistance. Photocatalysis using semiconductor oxides can degrade such compounds under light. In this work, Copper Bismuth Oxide ($CuBi_2O_4$) nanostructures were prepared and tested as a photocatalyst for metronidazole degradation under ultraviolet light.

Materials and Methods:

$CuBi_2O_4$ was synthesized by a hydrothermal method. Copper nitrate and bismuth nitrate were dissolved in deionized water. Sodium hydroxide was added dropwise to reach pH 14. The mixture was processed in a Teflon lined autoclave at 180°C for 10 h, then cooled, washed with water and ethanol, and dried at 105°C for 30 min. The material was characterized by X-ray diffraction with Rietveld refinement, field-emission scanning electron microscopy (FE-SEM), high-resolution transmission electron microscopy (HR-TEM), X-ray photoelectron spectroscopy (XPS), and UV-Vis diffuse reflectance spectroscopy. Photocatalytic tests were done under a UV lamp. Metronidazole concentration was tracked by UV-Vis absorbance at 319 nm. The effects of solution pH (5, 10, 11, 12) and catalyst dosage (0.3 g/L, 0.4 g/L, 0.5 g/L) were studied at an initial metronidazole concentration of 10 ppm.

Results and Discussion:

XRD confirmed a single phase tetragonal $CuBi_2O_4$ with space group P4/ncc. SEM and TEM showed a dumbbell-like cluster morphology with nanorod structures on the surface. XPS confirmed Cu, Bi, and O; it showed mixed copper oxidation states Cu^+ and Cu^{2+}. O 1s spectra indicated lattice oxygen, oxygen vacancies, and hydroxyl groups. UV-Vis analysis gave an indirect band gap of about 1.44 eV and a direct band gap of about 1.83 eV. Following pseudo-first-order kinetics with a 0.4 g/L catalyst dose, degradation efficiencies after 80 min were 27.7% at pH 5, 71.5% at pH 10, 82.4% at pH 11, and 87.1% at pH 12. Higher dosage reduced performance, which was linked to light blockage and particle aggregation. The high activity is attributed to increased surface area, effective charge separation, and the generation of reactive hydroxyl and superoxide radicals.

Conclusion:
$CuBi_2O_4$ nanorods demonstrate strong potential as an efficient and low-cost photocatalyst for degrading metronidazole in wastewater. The material's narrow band gap and unique morphology contribute to its high photocatalytic performance under UV light. As a result, it offers a promising solution for pharmaceutical pollutant removal.

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Exploring the fabrication of graphene-Based reusable electrodes for neurostimulation applications using solvent replacement.

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Introduction
Smart garment technology has become a rapidly advancing field in science. Electronic textiles (e-textiles), involve the integration electronics into traditional fabrics, enabling innovations in areas such as sensing, continuous monitoring, and neuromuscular rehabilitation, including using electrostimulation. For these functions, electrodes must be placed throughout the garment to help deliver current comfortably. Hydrogels are traditional modality for electrodes; however, these are disposable and therefore would not be practical in a smart garment. Combining conductive material with an elastomer create composites that are promising for reuseable electrodes. This study investigates various dispersion strategies to incorporate aqueous graphene dispersions into a polydimethylsiloxane (PDMS) elastomer matrix with the aim of fabricating conductive composites for electrostimulation.

Methods & Materials
Electrodes were prepared using SYLGARD™ 184 PDMS elastomer and a 4 wt% water-based graphene dispersion. Solvents included toluene, acetone, isopropyl alcohol, ethyl acetate, methylene chloride, hexanes, tetrahydrofuran (THF), acetonitrile, dimethyl sulfoxide (DMSO), 2-methylbutane, and tert-butanol. Commercial Nanoleq ElectroSkin© STIM electrodes (Myant) were used as controls.
Two different methods were explored. First, the preparation of the electrodes involved the direct mixing of the graphene aqueous dispersion with the PDMS base agent. After, the solvent exchange method was explored to overcome the graphene dispersion issues. The solvent exchange method was explored in three phases: first to find a potential solvent that worked, then to find if other solvents worked, and finally to further explore a safer solvent option.
Characterization methods consisted of Fourier transform infrared spectroscopy (FTIR), optical microscopy, scanning electron microscopy (SEM), impedance spectroscopy.

Results & discussion
In terms of the direct mixing method, initial, but spotty conductivity was observed for samples graphene loading of 4g, and 5g per 1g of PDMS was inspected by a multimeter; however, conductivity was lost often two weeks. In contrast, after phase one, toluene demonstrated an impedance of 738 Ω at 5KHz, demonstrating conductivity. Additionally, FTIR scans demonstrated that the peaks of the composite material mimic those found in PDMS and are not matching those found in the toluene control. This confirms the evaporation of toluene from the samples.

After further solvent investigation, ethyl acetate also demonstrated conductivity, with an impedance of 2927 Ω at 5kHZ. This offers a green alternative to achieve graphene dispersion within the PDMS matrix. Next, graphene loading concentrations was further explored using ethyl acetate, with loading concentrations of 3.5%, 5.7%, 6.8%, and 8.3%. Across the electrodes surface, the impedance of the electrode with an 8.3% graphene loading concentrations was comparable to the commercially available Nanoleq ElectroSkin© STIM electrodes; however, the impedance transverse was not comparable, demonstrating the importance of including a conductive textile under the conductive composite. Additionally, as graphene loading concentration increased, the mechanical integrity of the electrode decreased. Further exploration is required to optimize the trade-off between the composite's mechanical integrity and conductivity.

Conclusion
The current study explores a solvent-exchange strategy for fabricating reusable graphene–PDMS textile electrodes suitable for electrical neurostimulation using an environmentally friendly solvent and an aqueous graphene dispersion. Using an aqueous graphene dispersion avoids respiratory hazards associated with handling nanoparticles while achieving adequate filler dispersion and replicable electrical performance. This work provides the benchwork for a scalable foundation for the development of sustainable, wearable neurostimulation interfaces.

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Challenges and Opportunities of Fire Protective Clothing Fit, Function, and Safety Among Female Firefighters.

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Introduction
Fire protective clothing (FPC) is a critical part of the toolkit used to protect firefighters. However, the level of protection offered by FPC may be lower than expected if it is poorly fitted. It may create new hazards, e.g., as the garment interferes with the actions of the firefighter. Ongoing research has suggested that female firefighters face greater difficulties in finding FPC that is adequately fitted, leading to modifications of FPC, improper garment use, and overall interference of FPC with work activities. The objective of this study was to collect data on female firefighters' turnout gear, including the fit of the gear, the impact of the fit on the firefighter's safety, and modifications made to the turnout gear.

Methods
An online, mixed-methods survey was conducted in Qualtrics. The survey was distributed to female firefighters, ages 18-65, in the USA and Canada. A snowball sampling technique was used to recruit participants via contact with individual firefighters, fire stations, and relevant firefighting organizations. The survey was divided into five sections: demographic information, turnout gear information, fit of existing garments, modifications, and efficacy of modifications. Each section contained a mix of open-ended and multiple-choice questions to fully capture the experience of participants. Quantitative data from the survey was analysed using descriptive statistics in Excel.

Results
A total of 376 participants were included in the data analysis. Participants were from diverse locations throughout the US and Canada. Approximately 70% of respondents were career firefighters, with 22% being volunteer firefighters. 58% of the respondents described wearing custom gear as their primary set of turnout gear, versus only 37% for the secondary set. Only 14% of firefighters reported having access to women's specific PPE, with only 7% actually using some form of women's specific PPE. The majority of respondents rated their turnout gear as bulky (78%), too large (52%), and somewhat difficult to move in (57%). The most problematic elements of the turnout gear were the gloves, pant crotch, pant hip, helmet, and SCBA. In contrast, the boots, armhole width, and sleeve length had the highest rates of satisfaction. 20% of participants reported performing a modification on their gear. Most commonly, participants modified an element of their

turnout gear aside from the suit (e.g., gloves, boots, helmet). As well, nearly half of the participants stated that they wore something other than a station uniform underneath their turnout gear.

Conclusion

Results indicate that female firefighters in North America continue to face significant issues in accessing well-fitted fire protective clothing and equipment. In particular, there are significant issues with additional equipment, such as the helmet, gloves, and SCBA, which may be attributed to a limited size range for these items. Additionally, rates of modifications indicate the need for further research into the safety of FPC when it is not worn as intended.

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Manufacturing Cellulose Pulp for Lyocell Fibre from Flame Resistant Cotton/Nylon Waste Fabric.

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Introduction:

Globally, the textile industry generates over 92 million tonnes of textile waste annually, much of which ends up in landfills. Additionally, cotton production cannot keep up with the increasing global demand for cellulosic fibre. By recycling waste fabric, we can close this gap of demand and also reduce waste. However, many modern garments are produced using blended fibres like cotton combined with synthetic polymers. This is also true for protective clothing, which may include the presence of finishes to provide added functionality such as flame resistance. This project explores the use of flame resistant (FR) cotton/nylon fabrics as a feedstock to produce cellulose pulp for lyocell regenerated cellulose fibre manufacturing.

Materials and Methods:

The fabric used was an 88% cotton-12% nylon FR fabric (FRCN). It was washed and milled before being processed. The nylon content was removed using 90% formic acid. The nylon removal efficiency was assessed by gravimetry, Fourier transform infrared spectroscopy (FTIR), and CHNSO elemental analysis. The dissolved nylon content was also coagulated with water and weighed. After successful removal of the nylon content, different solutions were explored to lower the metal content in the sample as transition metals can lead to runaway thermal reactions during the lyocell process. Solutions investigated included the use of chelating agents and hydrolysis with sulfuric acid. The residual metal content was measured by inductively coupled plasma optical emission spectroscopy (ICP-OES) while the quality of the cellulosic molecule was assessed via intrinsic viscosity.

Results and Discussion:

The efficiency of formic acid for the removal of the nylon content from FRCN was evidenced by the strong reduction in the nylon FTIR peaks and a drop in the nitrogen content (indicating nylon presence) to a value like that of a 100% cotton FR fabric. Weight loss values were around 12-15%, i.e., close to the initial nylon content in FRCN. While the intrinsic viscosity of FRCN before treatment was around 350 mL/g, i.e., within the optimal range for lyocell pulp, the formic acid treatment only minimally affected the sample intrinsic viscosity, which indicated a preservation of the quality of the cotton fraction. The formic acid treatment conditions were optimized in terms of liquor ratio and treatment time.

As the iron content of FRCN was initially above the 10 ppm limit for the lyocell process, chelation was attempted using the traditional EDTA-SHMP combination but failed to reach the 10ppm threshold. Treatment by hydrolysis lowered the iron content closer to the threshold but also significantly reduced intrinsic viscosity. On the other hand, the use of DTPA as a chelating agent brought the iron content to a satisfactory level with preserving the intrinsic viscosity. Throughout all these treatments, the phosphorus content associated with flame resistance was maintained above 20,000 ppm.

Conclusion:
This study indicates the potential of flame-resistant blended cotton waste fabric as a feedstock for the preparation of flame-resistant regenerated cellulosic fibres through the lyocell process. It opens a new perspective for the recycling of used FR protective clothing into new FR garments.

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Test method of the resistance of joule heating textiles to fatigue bending.

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Introduction
Joule heating textiles have found applications in a wide range of commercial products, including jackets, socks, gloves, and vests. However, despite their worldwide market, the lack of standard test methods to assess the quality of these products is an obstacle to further growth. As part of a larger initiative aimed to develop a set of universal test methods to assess the efficiency, durability, and safety of joule heating textiles, this project focuses on the development of a test method for the measurement of the resistance of Joule heating textiles to fatigue bending. Indeed, Joule heating textiles are subject to frequent bending during regular use as part of a garment for example; this can lead to the degradation of the electrical conductivity and heating performance over time.

Materials and methods
The study used a test bench designed by a former intern in the project to evaluate the durability of Joule heating textiles under repeated fatigue bending. The test apparatus consists of a frame with a fixed horizontal board and a rotating board actuated by a servo motor. The specimen is secured across the junction between the two boards. The movement of the rotating board flexes in the specimen across its center. It uses a bending frequency of 1 Hz and a bending angle of 150° as they correspond to the average frequency joint and movement observed during normal human walking. The test was conducted with five Joule heating textiles corresponding to different textile structures and materials found in commercial products: woven fabric with silver coated and carbon yarns, silver plating on a knitted fabric, nonwoven fabric including silver-coated fibers, carbon filaments stitched on a fabric, and inserted conductive wire in a fabric. The heating performance of the Joule heating textiles was evaluated initially and after selected numbers of cycles using a heating efficiency test method previously developed as part of the project. It involves recording the temperature increase at the surface of the specimen when it is powered for 1 hour.

Results and discussion
The results demonstrated significant structure-dependent differences in the resistance of the heating textiles to fatigue bending. For the woven and plated knit fabrics, the heating efficiency remained relatively stable up to 20,000 bending cycles. Yet, for the plated knit, the heating rate increased with the number of bending cycles. The heating efficiency of the nonwoven and stitched reduced with the number of bending cycles; the decrease was 25% and 19% after 20,000 bending cycles, respectively. The inserted fabric demonstrated the least resistance to bending. After only 2,500 bending cycles, a

complete loss in heating performance was observed. It was attributed to a fracture in the metal strip making up the conductive part of the encapsulated heating wire.

Conclusion

This study constitutes an important step in the development of the standardizable test method of the resistance of Joule heating textiles to fatigue bending. It also reveals different levels of resistance of the heating efficiency with fatigue bending depending on the fabric structures. These findings indicate a promising path toward improved durability testing of wearable heating systems.

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Smart Garment Prototype for Muscle Expansion Monitoring During Resistance Training.

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Introduction

The integration of sensing functionality into textiles remains a significant challenge due to the difficulty in bridging rigid electronics with flexible textiles and durability issues, such as after exposure to repeated deformation and laundering. Conductive yarn–based strain sensors offer a viable approach for monitoring body changes for applications such as measuring the expansion of muscle during a workout or measuring breathing rate. This work presents a smart garment prototype called the "SmartWorkout Shirt" which is designed to track resistance training progress and monitor the longitudinal trend using textile strain sensors. The primary objective of this work is to explore the potential of smart garments and learn more about integration techniques for smart garments.

Methods & Materials

The garment is a tight-fitting shirt meant to be worn during workouts, allowing for close proximity with the skin for the best sensor response. The shirt is made of a polyester-cotton blend knit fabric, which has excellent elasticity and breathability. Textile strain sensors used for muscle expansion and breathing rate monitoring are made from silver-plated nylon 66 yarn (Shieldex & V Technical Textiles, Newark, NY). The temperature sensor is a low-power linear active thermistor IC (SparkFun Electronics, Boulder, CO). An OM5 series modular signal conditioner (DwyerOmega, Michigan, IN) is used to amplify and condition the strain data. A 3.7V LiPo battery powers the onboard microcontroller, a LilyPad Arduino (SparkFun Electronics).

Results & Discussion

The strain sensors for muscle expansion and breathing rate monitoring are based on the piezoresistive principle, where a change in resistance is produced when the fabric is stretched. Sensors were constructed by embroidering conductive yarn onto the fabric of the shirt in a sinusoidal pattern. By placing the sensors circumferentially around the upper arm and chest, data related to biceps/triceps activation and thoracic expansion during exercise can be gathered. A temperature sensor is also attached to the sleeve to give insight into workout intensity and blood flow.

Sensor data is acquired and processed using the Lilypad and stores strain data internally. This data is then exported to a computer using an FTDI board. Electronic components are mounted on detachable Velcro pads to ensure the shirt can be laundered after use.

Initial tests of the strain sensor successfully captured the change in arm circumference associated with an arm pump during an exercise. However, repeated tests damaged the conductive yarn and affected the sensor response. Further work will explore the use of polydimethylsiloxane (PDMS) to encapsulate the conductive yarn to improve the sensor durability. Adhesion of PDMS on the yarn will be characterized using optical microscopy, while mechanical durability will be assessed in terms of resistance to fatigue stretching and laundering.

Conclusion

The first prototype of a SmartWorkout Shirt has been developed with the ability to monitor muscle expansion and breathing rate using a textile strain gauge. It highlights key challenges related to durability towards the development of robust smart garments.

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Mapping the electrospinning parameter space for bead-free PAN/N-halamine composite nanofibres.

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Introduction

Electrospinning is an effective and adaptable technique for producing polymeric nanofibrous materials with high surface area, tunable morphology, and functionality. Polyacrylonitrile (PAN) is one of the most widely used polymers for electrospinning due to its good solubility in polar solvents, excellent spinnability, and mechanical robustness. Incorporation of N-halamine precursors into PAN matrices offers a promising route toward functional fibrous materials. However, the addition of such compounds can significantly influence the solution properties and electrospinning behaviour. Achieving uniform, bead-free fibres therefore requires careful control of the electrospinning parameters. This study investigates the effect of key processing conditions on the electrospinning of PAN blended with an N-halamine precursor to identify a stable operating window for nanofibrous mat formation.

Materials and Methods

PAN powder (average Mw 150,000 g.mol-1) was purchased from Aldrich, Canada. N,N-dimethylformamide (DMF) was obtained from Fisher Chemical, Canada. The N-halamine precursor, poly[5,5-dimethyl-3-(3′-triethoxysilylpropyl) hydantoin] (PSPH), was synthesized in the laboratory. PAN solutions were prepared at a concentration of 10 wt% using DMF as the solvent. PSPH was added at 30 wt.% relative to the PAN content to form a homogeneous solution. Electrospinning was carried out using a single-needle syringe pump setup under controlled ambient conditions of 20 ± 2 °C and 25 ± 5% relative humidity. The applied voltage, needle tip-to-collector distance, and solution flow rate were systematically varied to evaluate their influence on fibre morphology. Following electrospinning, the fibrous mats were dried to remove residual solvent. Fibre morphology was examined using Scanning Electron Microscopy (SEM), while Fourier Transform Infrared Spectroscopy (FTIR) was used to confirm the presence of characteristic functional groups associated with both PAN and the N-halamine precursor.

Results and Discussion

The electrospinning behaviour of the PAN/PSPH system was strongly influenced by processing parameters. At lower voltages and shorter tip-to-collector distances, insufficient stretching of the polymer jet resulted in bead formation and non-uniform fibres. Conversely, excessively high voltages led to jet instability and inconsistent fibre deposition. A preliminary operating window was identified through systematic variation of electrospinning conditions. Bead-free and smooth fibres were consistently obtained at applied voltages between 15 and 20 kV, tip-to-collector distances of 15 to 18 cm, and flow rates of 1.0 -1.5 mL h-1. SEM images revealed continuous fibres with smooth surface morphology and relatively uniform diameters of 210 ± 20 nm. FTIR spectra confirmed the successful incorporation of the N-halamine precursor into the PAN fibres, as evidenced by characteristic absorption bands from both components. The retention of these functional groups indicates that electrospinning did not adversely affect the chemical structure of the blended system.

Conclusion

This study demonstrates the successful fabrication of PAN/PSPH composite nanofibres via electrospinning under controlled environmental conditions. A stable processing window supported the production of smooth, bead-free fibres with consistent morphology and confirming effective integration of the PSPH precursor within the PAN matrix. These findings establish electrospun PAN/PSPH mats as a promising platform for N-halamine based functional materials. Future investigations will focus on activating the N-halamine functionality and evaluating antimicrobial efficacy, chlorine rechargeability, and durability to support the development of advanced self-decontaminating nanofibrous materials.

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Exploring Daily Life Challenges in Individuals with Musculoskeletal Weakness: Informing Adaptive Clothing Design.

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Introduction:

The World Health Organization recently estimated that 16 % of the global population (1 in 6 or approximately 1.3 billion people) have severe disability. That number includes mobility challenges that can be directly related to musculoskeletal weakness. This presentation gives an overview of the results of a literature review to identify how musculoskeletal weakness can impact daily life activities, and how the clothing people wear can help or hinder this. This review provides foundational knowledge to assist with the development of adaptive clothing design in the SmartWear project.

Methods & Materials:

The integrative literature review method reviewed 39 sources, including articles, books, and reports, on the topic of disability due to musculoskeletal weakness. This type of review collects knowledge of the current state of science, contributes to theory development, and is directly applicable to practice and policy, especially in the development of adaptive clothing design. The review outlined 1) the origins of musculoskeletal weaknesses, 2) health assistive devices often used by individuals living with musculoskeletal weaknesses, 3) difficulties that people can potentially face in daily life, and 4) existing adaptive clothing design strategies.

Results & Discussion:

The research showed that musculoskeletal weaknesses are varied in origin: they include neurologic, genetic, and endocrine causes, and may also be due to medication, toxins, and infections. In some instances, individuals experiencing musculoskeletal weakness may need to use devices to aid with mobility (e.g., cane, walker, wheelchair). They may also require health assistive devices attached permanently or temporary to the body to treat certain concurrent and/or associated health conditions (e.g. temporary devices like braces, glucose monitors or permanently attached devices such as insulin pump, ostomy bags, or urinary catheter). In addition to mobility limitations, individuals with musculoskeletal weakness often experience secondary concerns such as obesity, dizziness, impaired balance, visual challenges, and increased risk of falls. These combined challenges significantly affect dressing practices and clothing usability. The review identified a lack of adaptive clothing options that meet both functional and aesthetic expectations. Individuals with severe mobility limitations may require dressing while lying in bed, restricting clothing choices. Wheelchair users also reported issues with insufficient pant length when seated. Additional concerns included difficulty with emergency undressing, sleeve interference with mobility aids, fabric durability, and challenges with temperature regulation. Existing adaptive clothing strategies described in the literature include alternative closures and pattern design modifications.

Conclusion:
This integrative review highlights the impact of musculoskeletal weakness on daily-life activities and clothing-related experiences. Clothing is a critical factor influencing independence, comfort, safety, and self-esteem. Adaptive clothing options currently remain limited in functionality, inclusivity, and aesthetic appeal. The findings emphasize the importance of adaptive clothing design that accommodates diverse physical conditions, assistive devices, and mobility needs while being stylish and desirable to wear. They will support the development of adaptive clothing designs for people with musculoskeletal weakness in the SmartWear project, including adjustments to clothing pattern blocks and construction techniques, and the use of alternative closure systems.

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Extraction of Bio-based Glycerol from Catfish for Salt-free Reactive Dyeing of Cotton and Dyed Fabric Performance Evaluation.

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Introduction
The traditional reactive dyeing process of cellulosic fabrics requires the use of inorganic salts, such as sodium sulfate, which causes significant environmental pollution of wastewater streams. This study investigated the potential application of glycerol, obtained from the fat-rich by-products of a Bangladeshi catfish (Pangasius hypophthalmus), as an alternative to inorganic salt in traditional reactive dyeing. The colour strength, colour fastness, and physico-mechanical properties of bio-based, glycerol-dyed fabrics were compared with that of salt-dyed fabrics.

Materials and Methods
The catfish tissues were heated and mechanically pressed to extract crude oil (primarily composed of triglycerides). Next, the crude oil was centrifuged to remove suspended impurities. Alkaline hydrolysis was performed twice to break down the triglycerides into glycerol and fatty acids, during which fatty acids transformed into soap. Finally, a salt solution was added to the glycerol-rich solution to facilitate the precipitation of the soap from the mixture and improve the purity of the glycerol.

The fabric used for the study was a 100% cotton knitted single jersey, with a mass per unit area of 140 g/m^2. A scouring and bleaching pretreatment was carried out using NaOH and H2O2. The pretreated fabric was then treated with glycerol (without any salt), followed by dyeing in an alkaline medium at 60˚C for 30 minutes. The dyeing of the same cotton fabric was also performed using Glauber salt in an alkaline medium, as per the traditional reactive dyeing process.

The colour strength of the dyed fabrics was determined using a spectrophotometer (Datacolour 650, USA). The colour fastness to washing and rubbing (i.e., both dry and wet) was determined as per ISO 105-C06:2019. Finally, the physico-mechanical properties of the dyed fabrics were assessed with respect to the mass per unit area (ISO 3801:1977), bursting strength (ISO 13938-1:2019), tear strength (ASTM D1922:2023), and crease recovery angle (ISO 2313-2:2021).

Results & Discussion

The average colour strength (K/S) of glycerol-treated and traditionally dyed fabric samples was 16.25 and 10.71, respectively, indicating a darker shade and increased dye absorption for the glycerol-treated fabric. For the glycerol-treated fabric, the colour fastness to washing and wet rubbing rating was 4-5/5, whereas the dry rubbing rating was 5/5, which was comparable to the performance of the fabric dyed following the traditional reactive dyeing process.

The mass per unit area and the bursting strength of the glycerol-treated fabrics were approximately 7 % higher than those of salt-dyed fabrics. Similarly, the tear strength and crease recovery angle of the glycerol-treated fabrics were 30% and 22 % higher, respectively, than those of the salt-dyed cotton fabrics. This suggests that the glycerol-treated fabric might have suffered less damage than the fabric dyed in the presence of inorganic salt.

Conclusion

The dyed, glycerol-treated fabric demonstrated increased colour strength, comparable colour fastness properties, and better physico-mechanical behaviour than the salt-assisted reactive dyed fabric. These results suggest that bio-based glycerol is a promising substitute for inorganic salt in the reactive dyeing process of cellulosic fabrics.